Global Air-Ocean Coupling Development and Studies

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LONG-TERM GOALS

The Navy has a need for global environmental prediction from the top of the atmosphere to the floor of the ocean. Forecast time scales are 7-10 days for the atmosphere and 30-60 days for the ocean. A coupled atmosphere-ocean prediction system for data-assimilation and forecast provides the best hope for achieving these ambitious goals. NRL-Monterey will develop the system with large contributions from the rest of NRL and the meteorological and oceanographic research communities at large. The target system with have horizontal resolution of O(1/4) degree in the atmosphere and O(1/8) degree in the ocean.

OBJECTIVES

Our objective is to develop, test, and validate a global, scalable, coupled data assimilation system comprised of atmosphere and ocean components. The atmosphere and ocean components will each contain programs to perform data quality control, data analysis, initialization, and numerical forecasts. This coupled system will be used in this and other programs for basic and applied research topics and is also expected to eventually transition to operations through a related 6.4 program. In operations, it is expected that this system will provide improved capabilities to describe the atmosphere and the ocean at the analysis and forecast times and to provide high resolution initial and boundary data for the atmosphere, ocean, and ice to a mesoscale coupled data assimilation system.

APPROACH

Our approach is to build the coupled system using a combination of existing and newly-developed components and a generalized flux coupler to allow for the exchange of relevant parameters across the air-ocean interface. For the atmosphere, the Navy Operational Global Atmospheric Prediction System (NOGAPS) has been shown to be among the leading atmospheric data assimilation systems in the world. NOGAPS will be used for the atmospheric component of the coupled system. For the ocean component, we will leverage work on-going at other institutions [e.g., Naval Postgraduate School (NPS), NRL Stennis Space Center (NRL SSC), Los Alamos National Laboratory]. Some of these projects include the development of a 3-dimensional ocean multivariate optimum interpolation analysis (3D MVOI, NRL MRY and NRL SSC), the testing of the Parallel Ocean Prediction (POP) ocean model at NPS, and the development of the next-generation Polar Ice Prediction System (PIPS 3.0) in a joint project headed by NRL SSC. The coupled system will be designed for scalable computer architecture. Initial development will involve the testing and/or development of key components of the system, improvements to parameterizations of NOGAPS physical processes that are critical for accurate simulation of air/sea energy exchange, and the development of atmospheric datasets that can

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14. ABSTRACT

The Navy has a need for global environmental prediction from the top of the atmosphere to the floor of the ocean. Forecast time scales are 7-10 days for the atmosphere and 30-60 days for the ocean. A coupled atmosphere-ocean prediction system for data-assimilation and forecast provides the best hope for achieving these ambitious goals. NRL-Monterey will develop the system with large contributions from the rest of NRL and the meteorological and oceanographic research communities at large. The target system with have horizontal resolution of O(1/4) degree in the atmosphere and O(1/8) degree in the ocean.

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be used for the validation of the ocean model. This development will transition to a related 6.4 project that will focus on the design and implementation of this system for operational use.

WORK COMPLETED

Testing began of a complete prototype coupled ocean data assimilation system based on the strategy of a forecast model and objective analysis cycling analogously to the proven methods used in atmospheric data assimilation. The important property of such a strategy is that the background for the analysis, i.e. the "first guess", is a POP one day forecast from the previous analysis verifying at the current analysis time. Ocean data assimilation systems have historically used the previous analysis, i.e. a persistence forecast, as the background. The key components are the NOGAPS data assimilation system, which provides surface flux forcing, the global POP ocean model, and the Navy's ocean MVOI analysis system configured for the global ocean domain. Input data is the complete observational database available at the Fleet Numerical Meteorology and Oceanography Center (FNMOC). This includes in-situ and satellite sea surface temperature (SST) observations, temperature profiles from all available sources, altimeter data of sea surface height, and synthetic observations, e.g. MODAS. A relatively coarse horizontal resolution (0.5 deg) is used for POP to allow exhaustive testing of different data assimilation strategies. The primary objective at this time is to understand the way in which the widely disparate data types unique to ocean observations interact with a cycling data assimilation system.

We are now undertaking the task of improving the dynamical behavior of the atmospheric boundary layer (ABL) over the ocean. Detailed diagnostic studies (e.g. Duynkerke and Teixeira 2001) have shown that global models often underestimate clouds like stratocumulus that have a profound influence on the radiation budget of the ocean surface. In NOGAPS this underestimation was substantially corrected with a new cloud scheme (Teixeira 2001, Teixeira and Hogan 2002) implemented operationally in December 2000.. At NRL we have developed a new closure for the eddy-diffusivity scheme (Teixeira and Cheinet 2002) that parameterizes ABL turbulence and convection. In this new scheme the mixing–length is proportional to the square root of the turbulent kinetic energy (TKE). The constant of proportionality is a constant time-scale that is of the order of a few hundred seconds. This new scheme has been quite successful in simulating different types of ABLs: dry convective, stratocumulus and shallow cumulus (Cheinet and Teixeira 2002).

RESULTS

The first set of experiments we have run compared the performance of our forecast model/analysis cycling system to its performance using the persistence background, i.e. the POP model was removed.

Figure 1a is the monthly mean (August 2000) analysis increment of SST for the cycling system, fig 1b is the same quantity for the persistence based system. The assimilation system had been running for 3 months at this point. Clearly the POP model is able to predict daily changes in SST to give a better fit of the observations to the background in dynamically active areas. Input data for these results excluded subsurface observations, particularly the MODAS synthetics. Preliminary results with MODAS have been disappointing, and we believe that the large climatological influence in MODAS between sea surface height and subsurface temperature is often inconsistent with the POP model predictions of these variables. This is not surprising, since a climatological forecast is seldom a very good prediction of the instantaneous state of the ocean or atmosphere. Experiments are underway to assess the impact of other subsurface observations.

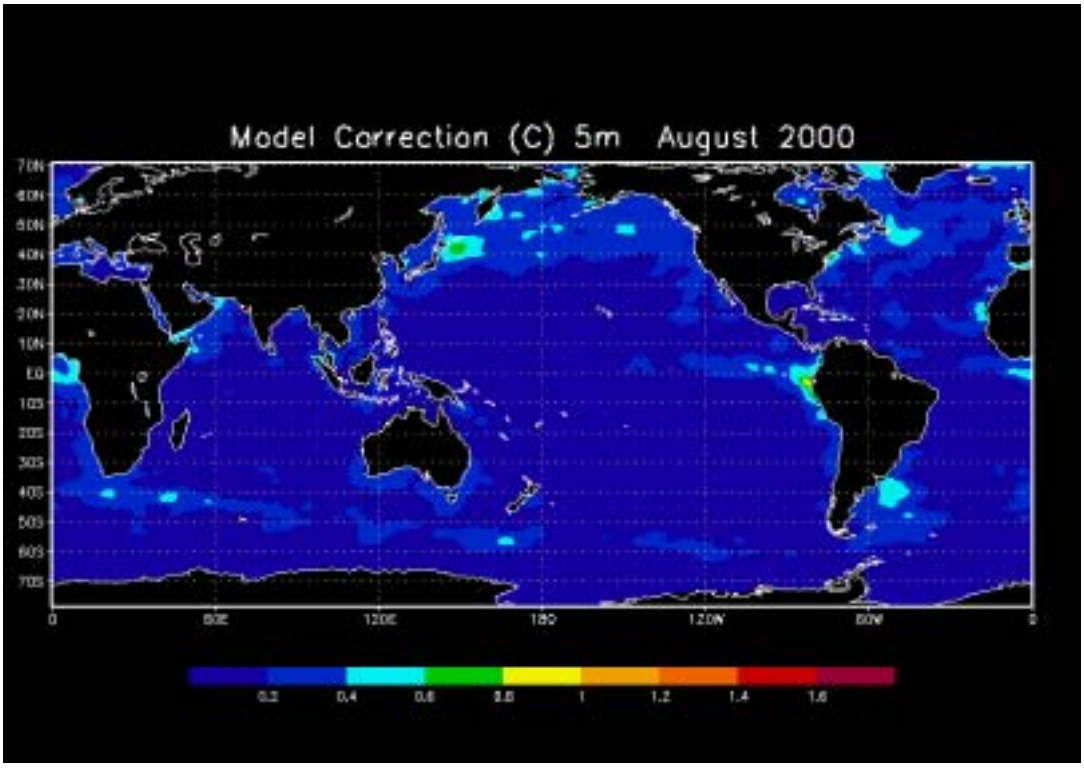
Model Correction (C) 5m August 2000
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Fig 1a

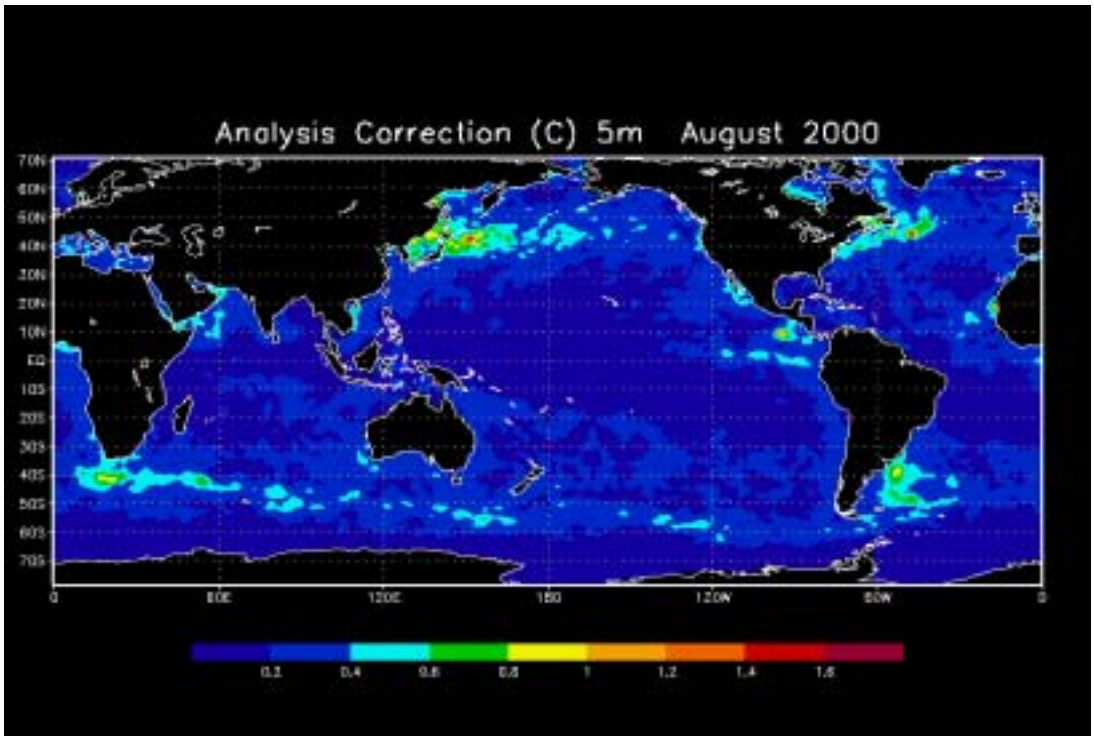
Analysis Correction (C) 5m August 2000
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Fig 1b

IMPACT

Operational atmospheric data assimilation is a mature technology practiced at several major national weather centers around the world. Ocean data assimilation, on the other hand, is still in its infancy. Lack of observational data and daunting computational requirements have been primary obstacles in its progress. Recent advances in observing systems and computer technology are finally removing these obstacles, but there are still major challenges. The Navy has a critical need for global oceanographic environmental information to complement the global meteorological support that impacts virtually all Navy operations. The NRL coupled data assimilation and forecast system is the first step toward this goal.

TRANSITIONS

The cycling coupled data assimilation system has been transitioned to 6.4 advanced development, where additional data impact studies are underway and plans are being made to transition a prototype system to FNMOC beta ops testing. The new cloud scheme was transitioned to the operational NOGAPS, and a new mixing length parameterization was transition to 6.4 advanced development.

RELATED PROJECTS

6.4 Global Coupled Data Assimilation System Evaluation (Award # N0003900WXDF217(A1)

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